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| (21) International Application Number: PCT/US98/04099<br>(22) International Filing Date: 3 March 1998 (03.03.98)<br>(30) Priority Data: 60/040,143 10 March 1997 (10.03.97) US<br>(71) Applicant: PRECISION DYNAMICS CORPORATION [US/US]; 13880 Del Sur Street, San Fernando, CA 91340 (US).<br>(72) Inventor: BEIGEL, Michael, L.; 1982 Sage Avenue, Corona, CA 91720 (US).<br>(74) Agent: MAHONEY, Thomas, P.; Suite 710, 660 Newport Center Drive, Newport Beach, CA 92660 (US).                                   |  | (81) Designated States: AU, BR, CA, JP, MX, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br><br>Published<br><i>With international search report.<br/>         Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |   |
| (54) Title: REACTIVELY COUPLED ELEMENTS IN CIRCUITS ON FLEXIBLE SUBSTRATES  |  |  |   |
| <p>The diagram shows a rectangular flexible substrate (12) with dashed lines indicating internal circuit elements (10, 14) and terminals (2). The substrate is shown in a perspective view, with dashed lines indicating its internal structure and the location of the circuit elements. The terminals (2) are located at the ends of the substrate. The circuit elements (10, 14) are located on opposite sides of the substrate, utilizing the resistance of the substrate in a reactive or inductive circuit.</p> |  |  |   |
| (57) Abstract<br><p>An RFID circuit for incorporation in an identification device which includes a polymeric substrate (12), the circuit being formed or integrally connected with said substrate whereby the substrate becomes a component of the RFID circuit. An embodiment of the circuit includes circuit elements (10, 14) printed or attached to opposite sides of the substrate utilizing the resistance of the substrate in a reactive or inductive circuit.</p>   |  |  |   |

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REACTIVELY COUPLED ELEMENTS  
IN CIRCUITS ON FLEXIBLE SUBSTRATES

This application claims the benefit of U.S.  
Provisional Application No. 60/040,143, filed March 10,  
5 1997.

This invention relates to RF circuits and,  
more particularly, to reactively coupled elements of  
said circuits, particularly those disposed on flexible  
substrates.

10 Background of the Invention

It is well known to those skilled in the art  
that the goal in the design and manufacture of RFID  
tags is to provide low-cost miniature components which,  
when assembled, will be susceptible of incorporation in  
15 a wide variety of applications where miniaturization  
and low cost are requisite.

Typical of prior art attempts at miniaturiza-  
tion and low cost are the arrangement of the components  
of the circuit in a uniform plane with the conductors  
20 incorporated in the circuit disposed in said plane.

However, the conductive securement of the IC  
circuit to the antenna continues to pose problems in  
that it increases the thickness of the assemblage and  
prevents the utilization of such combinations in many  
25 applications such as miniaturized RFID tags.

Consequently, in ultra-miniature circuits, for example RFID tags, miniaturizing circuit dimensions and decreasing production costs are ongoing objectives. Recent patents teach methods of implementing this  
5 miniaturization with respect to attachment of the integrated circuits to the antenna by the simplest, lowest profile and most economical means conceived of at the time (e.g., Marsh-Patent No. 5,566,441 and Moskovitz-Patent No. 5,528,222).

10      Objects And Advantages Of The Invention

An object of my invention is the provision of a circuit for eliminating conductors between the IC components of an RFID and the associated antenna materially reducing the overall cost and increasing the  
15 utility of the IC/antenna combination.

Another object of my invention is the provision of an RFID circuit wherein the electrical conductors between electronic circuit elements are supplanted by electromagnetically reactive capacitive coupling  
20 means, utilizing electrically conductive areas such as inks, films, or foils on thin insulating dielectric substrates.

Another object of my invention is the provision of circuits of the aforementioned character  
25 wherein inductive coupling means are utilized in substitution for said capacitive coupling means.

An additional object of my invention is the provision of circuitry of the aforementioned character wherein the conductive and capacitive coupling means are supplanted by the utilization of lumped coupling  
5 means.

A further object of my invention is the incorporation of an RFID circuit of the aforementioned character in an identification device utilizing flexible substrates, such as, for example, sheet polymer  
10 materials utilized in identification wristbands wherein the components of the RFID can be placed on superimposed strips of polymer sheets and electronic communication between the components of the RFID is established by capacitive coupling means.

15 An additional object of my invention is a provision of an assemblage of the aforementioned character wherein the capacitive coupling means is supplanted by inductive coupling means.

A further object of my invention is the provision of an RFID assemblage mounted in a flexible  
20 identification wristband formed from flexible polymers wherein superimposed laminae of said flexible polymers include an RFID circuit incorporating lumped electronic conductor means.

25 Other objects and advantages of my invention will be apparent from the following specification and

the accompanying drawings which are for the purpose of illustration only.

Brief Description of the Drawings

- 5                   FIG. 1: shows a reactively coupled RFID tag  
                  in capacitive coupling with a dipole  
                  antenna;
- FIG. 2: is a longitudinal sectional view  
                  taken on the line 2-2 of Fig. 1;
- 10                  FIG. 3: shows the coupling circuit means of  
                  Figs. 1 and 2;
- FIG. 4: is a block diagram of the components  
                  of Figs. 1-3;
- FIG. 5: is an RFID tag with capacitively cou-  
                  pled antenna elements on opposite  
15                  sides of the flexible substrate; and
- FIG. 6: is the circuit of Fig. 5.

Description of Preferred Embodiments of the Invention

Referring to the drawings, and particularly  
to Figs. 1 and 2 thereof, I show an integrated circuit  
20 chip 10 mounted on one surface of an elongated flexible  
substrate 12 such as a polymer strip and having a reac-  
tively coupled capacitive connection to a dipole  
antenna 14 on the other side of said strip.

There are various ways of attaching an inte-  
25 grated circuit to a substrate consisting of a polymeric  
film and, in the case of chip 10, the operative connec-

tion thereof to the substrate may be accomplished by adhesive means.

The antenna 14 may be imprinted on the opposite sides of the substrate by the utilization of conductive inks or may be provided in the form of conductive foils adhesively or otherwise secured in underlying relationship with the IC chip 10.

The capacitive coupling of the chip 10 to the antenna 14 is accomplished by terminal areas 17 on the chip 10 which overlie corresponding extremities 16 of the antenna 14. The terminal areas 17 of the chip 10 are electrically connected to the circuitry of the chip 10.

In addition to providing operative coupling, the capacitance (reactance) between the IC and the substrate can be utilized as a capacitive component in a resonant RFID antenna circuit or other resonant circuit.

Further, in the case of coupling of electronic circuit elements on opposite sides of a thin insulating dielectric film at appropriate frequencies, capacitive, inductive, or lumped reactive interconnection or coupling of the elements may be obtained by placing appropriate conducting areas or patterns on opposite sides of the film at the point of coupling. This can be accomplished by the adhesive attachment of

conductive foils or printing of conductive inks on the opposite sides of the film.

By the capacitive coupling of circuit elements, the need for electrical connections constituted by conductors through windows or vias in the substrate is eliminated. Consequently, the production of functional circuits by printing or similar processes in a continuous production line is simplified and enhanced. Moreover, the overall thickness and consequent size of the package is greatly reduced.

The circuit 18 of Fig. 3 shows the chip 10 connected to the dipole antenna 14 by the capacitive coupling 19. The capacitance of the overlying terminal areas 17 of the chip 10 and the extremities 16 of the dipole antenna 14 can be calculated by the formula for a parallel plate capacitor:

$$C(\text{in farads}) = \epsilon_r \epsilon_0 A/d$$

where

$\epsilon_r$  is the relative dielectric constant

$\epsilon_0$  is the permittivity of free space,

$$8.85 \cdot 10^{-12} \text{ farads/meter}$$

A is the plate area in  $\text{m}^2$

and d is the separation between the plates,

A is the area of the overlap, d is the distance between the plates,  $\epsilon_r$  is the dielectric constant of the substrate 12, and  $\epsilon_0$  is the permittivity of free space,



8.85\*10<sup>-12</sup> farads/meter constant. Thus, for an overlap area of 4 sq. millimeters, a distance of 0.1mm, and a dielectric constant 3.0, the capacitance of the coupling circuit is 1.062 pico-farads.

5           At a frequency of 2.4 GHz, the impedance of the capacitive reactance is equal to 62 ohms, which will resonate a circuit whose reactance is inductive on the order of 62 ohms. Assuming dimensions of the dipole antenna formed by the conductive antenna portions 14 are 2.6" of the total length by 1/8", then an  
10       antenna is formed which is resonant at 2.4 GHz. The circuit 18 is shown in Fig. 3 of the drawings wherein the capacitance 19 between the terminal areas 17 of the IC and the extremities of the antenna 14 is illustrated.  
15

          The block diagram of Fig. 4 shows a passive RFID tag incorporating the circuit elements of Figs. 1-3. A Reader-Programmer radiates an electromagnetic field to supply the tag with power and to communicate  
20       with the tag. The dipole antenna elements 14 are connected by the capacitive/inductive circuit 19 to an antenna interface 28 and the antenna interface is connected on one side to a power supply 30 which supplies power to control circuitry 32 and data storage 42, said  
25       data storage and computer circuitry being mutually

interconnected to a modulator 44 which is, in turn, connected to the antenna interface 28.

The power supply circuit 30 derives power by rectifying the voltage induced in the antenna 14. The  
5 RFID tag receives information by variations in the reader field and transmits signals to the reader by impressing a modulation signal on the antenna interface. Control circuits provide logic, timing, and control signals to the components of the tag IC appropriate for the complexity of the tag function and its communication protocol. Data storage circuitry 42 in the  
10 tag provides information storage ranging from A READ-ONLY ID number to a READ-WRITE database.

An alternative antenna arrangement is shown  
15 in Figs. 5 and 6 of the drawings as including overlapping antennas 52 and 54 on opposite surfaces of the substrate 50, the antenna 52 being of substantially truncated rectangular construction and the antenna 54 being of substantially loop construction and located  
20 internally of the antenna 52. Overlapping areas 56 of the antenna introduce series capacitances in the antenna elements.

At a frequency range of 900 MHz, capacitive coupling of the IC to the antenna is practical, but the  
25 effective length of the antenna must be longer than for operation at 2.4 GHz. In this case, the coupling is

used to provide antenna elements on both sides of the substrate with the antenna 52 located on one side of the substrate and the antenna 54 located on the other side of the substrate with the overlapping areas  
5 located in spaced relationship with each other through the medium of the polymer of the substrate.

The IC chip 60 is located in overlapping relationship with the bi-polar extremities of the antenna 52 and establishes a capacitive coupling in the  
10 manner previously described. In turn, the opposite extremities of the antenna 52 are disposed in overlapping capacitive relationship with the extremities of the antenna 54 on the other side of the substrate. In this manner, the length of the antenna is extended and  
15 much more capacitive reactance is provided. It should be kept in mind that series inductance between antenna elements increases the electrical length of the antenna and series capacitance decreases it. The antenna can be electrically longer by adding more elements and  
20 using capacitance to provide the connection. However, the capacitance must be of low impedance so as not to defeat the added elements.

Illustrated in Fig. 6 is the circuitry of the dual antenna combination wherein the dual capacitance  
25 is illustrated at 66 in relationship to the integrated

circuit 60. The loop antenna 54 is capacitively connected to the antenna 52 by the capacitances 66.

By the utilization of the dual antennae, the resultant is the equivalent of an antenna which is long  
5 enough to be resonant with the designed circuitry.

Although I have disclosed specific reactive circuitry utilized in conjunction with a polymer substrate, it will be obvious to those skilled in the art that alternative circuitry may be utilized without  
10 departing from the scope and spirit of the invention as defined in the claims.

## I CLAIM:

1. In a radio frequency circuit, the combination of:

a polymeric substrate; and

5 components of said circuit formed on opposite surfaces of said substrate in overlying relationship with each other whereby the resistance of said polymeric substrate creates a reactive relationship between said components.

10 2. In a radio frequency circuit, the combination of:

a polymeric substrate; and

15 components of said circuit formed on opposite surfaces of said substrate in overlying relationship with each other whereby the resistance of said polymeric substrate creates an inductive relationship between said components.

3. In a radio frequency circuit, the combination of:

20 substrate means including a plurality of polymeric laminae secured in overlying relationship with one another, said laminae including a top lamina, a bottom lamina, and an intermediate lamina disposed between said top and bottom laminae; and

25

circuit components formed on the top and bottom surfaces of said intermediate lamina to utilize said lamina as a circuit component.

4. The device of claim 3 wherein the circuit is a reactive circuit.

5. The circuit of claim 3 wherein the circuit is an inductive circuit.

6. The device of claim 1 in which the components of said circuit are imprinted in conductive ink.

7. The device of claim 1 in which the components of said circuit are fabricated from metallic foils.

8. The circuit of claim 1 which includes a plurality of antennae formed on opposite sides of said lamina in overlying relationship with each other.

9. The circuit of claim 8 in which said antennae are operatively connected by a reactive circuit.

10. The circuit of claim 8 in which said antennae are operatively connected by an inductive circuit.

11. In a circuit for an RFID, the combination of:

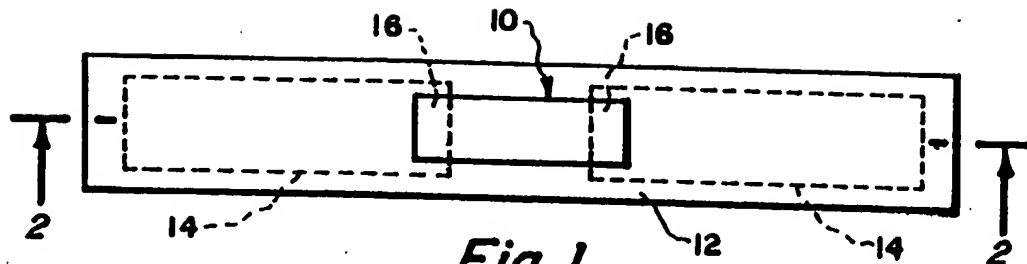
a polymeric substrate for said circuit, said substrate acting as a structural component of said RFID; and

5 circuit components formed on opposite surfaces of said substrate in overlying relationship of one component with another to incorporate said substrate as an operative component of said circuit.

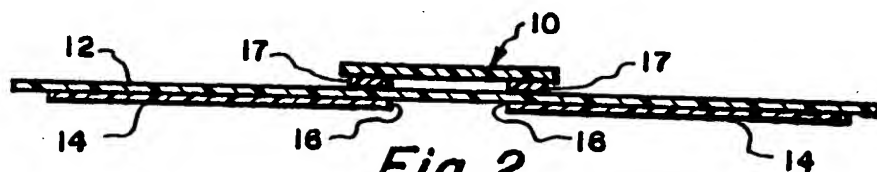
12. The circuit of claim 11 which is reactive and wherein said substrate operates as the dielectric component of said circuit.

13. The circuit of claim 11 which is inductive and wherein said substrate operates as the dielectric component of said circuit.

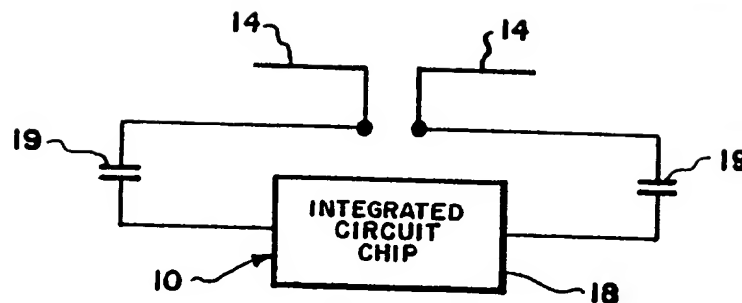
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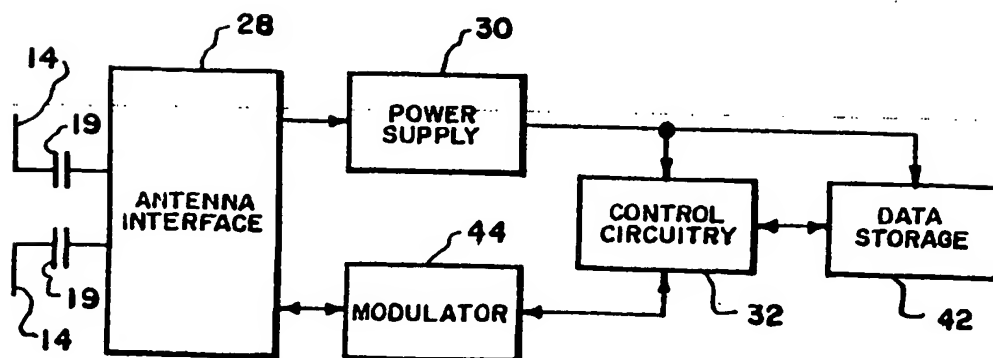
*Fig. 1.*



*Fig. 2.*



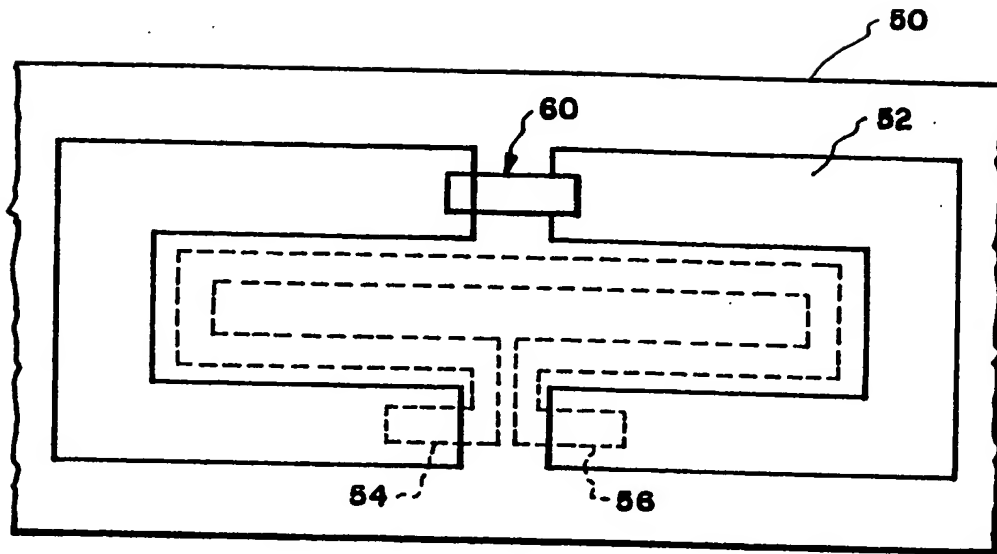
*Fig. 3.*



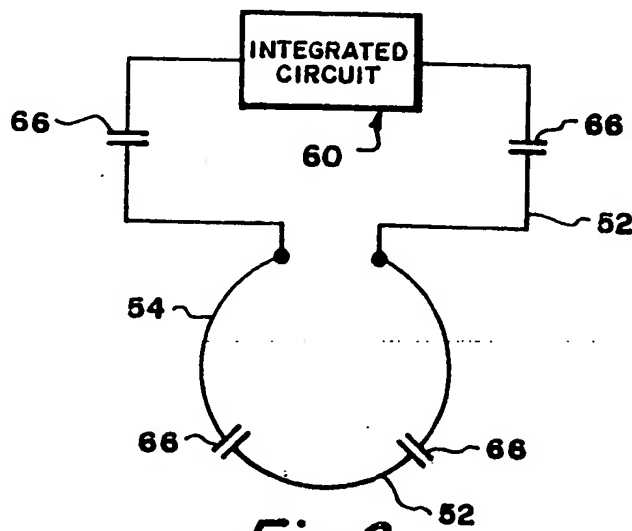
*Fig. 4.*



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*Fig. 5.*



*Fig. 6.*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/04099

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H01Q 11/12, 1/36; G08B 13/14, 26/00

US CL : 343/726, 742, 873, 895; 343/505, 572, 825.54; 235/492

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 343/726, 742, 873, 895; 343/505, 572, 825.54; 235/492

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
NONEElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
IC, ANTENNA, CAPACITY COUPLING

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category*   | Citation of document, with indication, where appropriate, of the relevant passages                 | Relevant to claim No. |
|-------------|--|-----------------------|
| X<br>—<br>Y | US 4,835,524 A (LAMOND ET AL) 30 May 1989 (30/05/89), figures 1 and 2.                             | 1-5, 11-13<br>6-10    |
| X<br>—<br>Y | US 5,142,270 A (APPALUCCI ET AL) 25 August 1992 (25/08/92), figures 1-3 and column 3, lines 51-59. | 1-5, 11-13            |
| Y           | US 5,223,849 A (KASEVICH ET AL) 29 Junw 1993 (29/06/93), see entire document.                      | 6 and 7               |
| Y           | US 5,608,417 A (DE VALL) 04 March 1997 (04/03/97), see entire document.                            | 8-10                  |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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